For Chengdu Workshop on ASIAEX 2001

Characteristic of the Internal Waves at Location of 126°54.32'E/ 29°24.01'N

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What the topic focuses on?

- Observation of Internal Waves in ECS ASIAEX 2001
- Features of the Temperature Fluctuation
- Characteristic of the Vertical Displacement Power Spectrum of Internal Waves
- Normal mode of internal wave and its dispersion including Phase velocities, group velocities, and eigenfunctions of normal modes

1. Introduction

Experiment Site:

126º54.32'E/29º24.01'N

Water depth of sea area: ~ 105m

2. Observation of Internal Waves

Survey Duration:

~ 63 hours from 08:40/Jun.3 to 0:00/Jun.6/2001

Survey Instruments:

17 WaDar Temperature Sensors from GIT

Sensor depths:

19.95, 23.1, 26.25, 29.4, 32.55, 35.7, 38.85, 42, 45.15, 48.3, 51.45, 54.6, 57.75, 60.9, 65.1, 71.4 and 79.8m

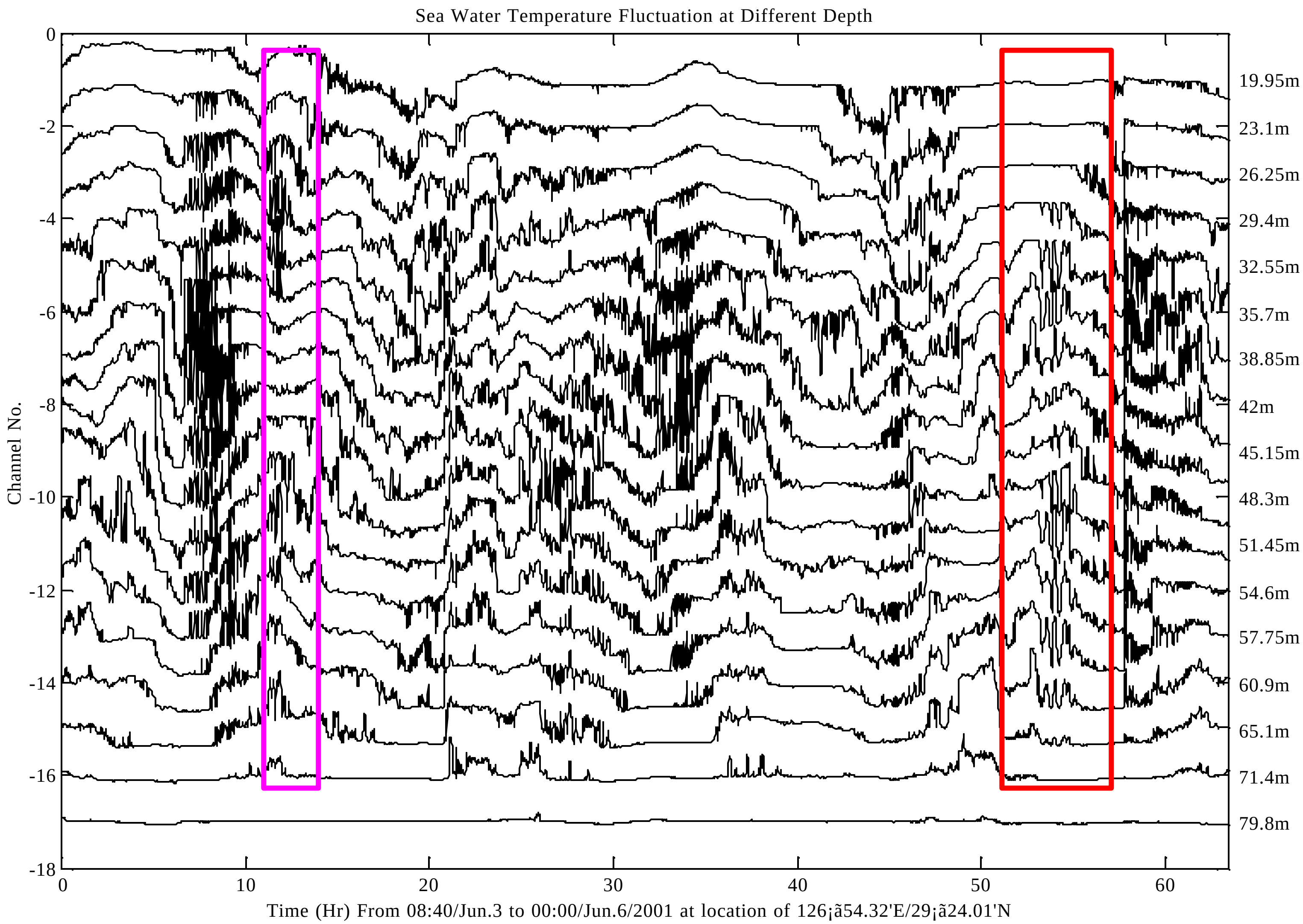


Figure 1 Sea water temperature data curves at different depth from 08:40/Jun.3 to 00:00/Jun.6/2001

Features of the Temperature Fluctuation:

- Three elevation solitons at 53:15, 53:46 and 54:14 which are separated from internal tides
- Thermocline Layer: from 20m to 75m
- Internal semi-diurnal tides with strong fluctuations at 8:00, 21:00, 33:00, 46:00 and 58:00
- Cool water-mass between 11:48 and 13:52

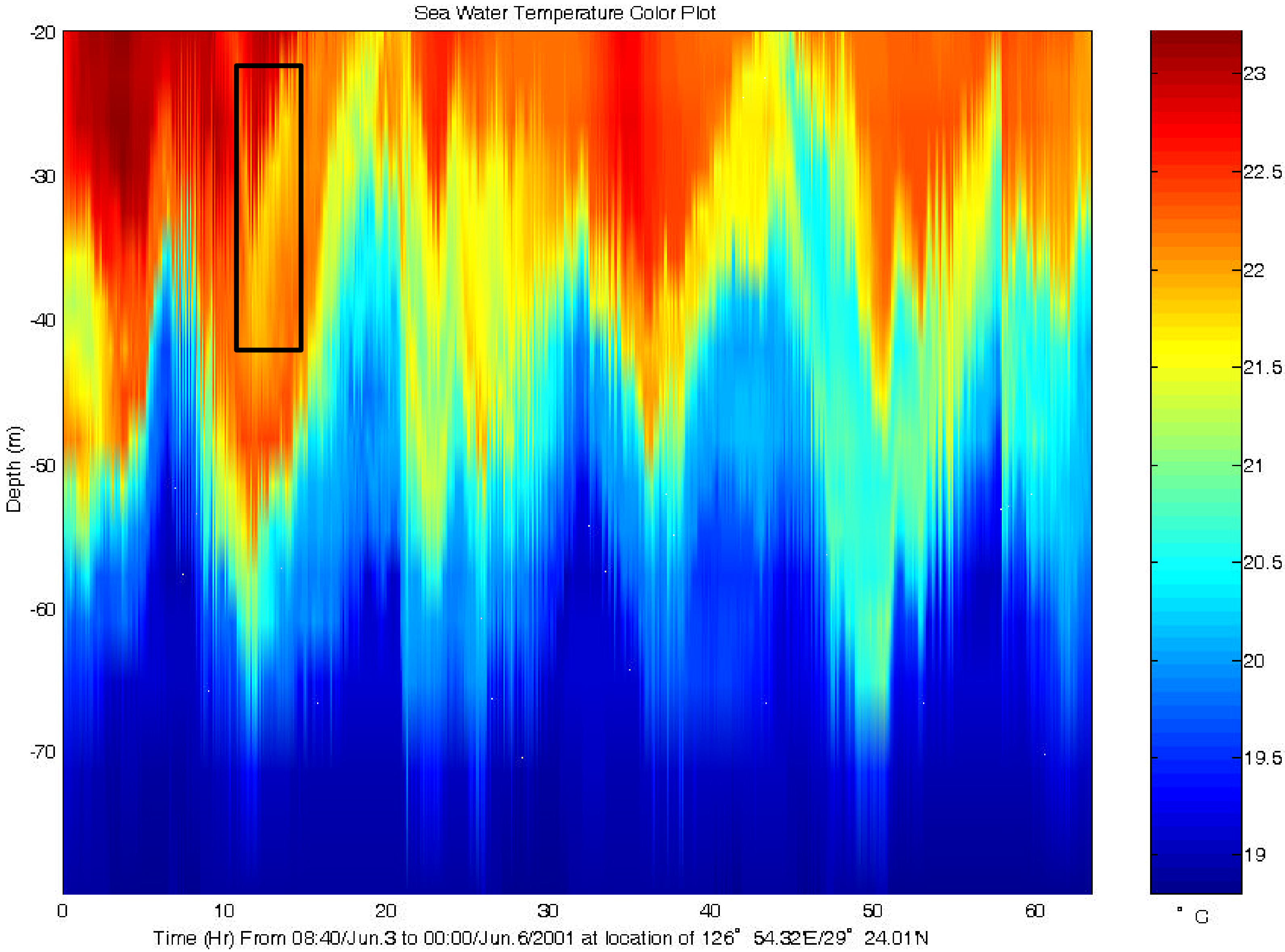


Figure 2 Sea water temperature distribution plot at different depth from 08:40/Jun.3 to 00:00/Jun.6/2001

3. Characteristic of the Vertical Displacement Power Spectrum of Internal Waves

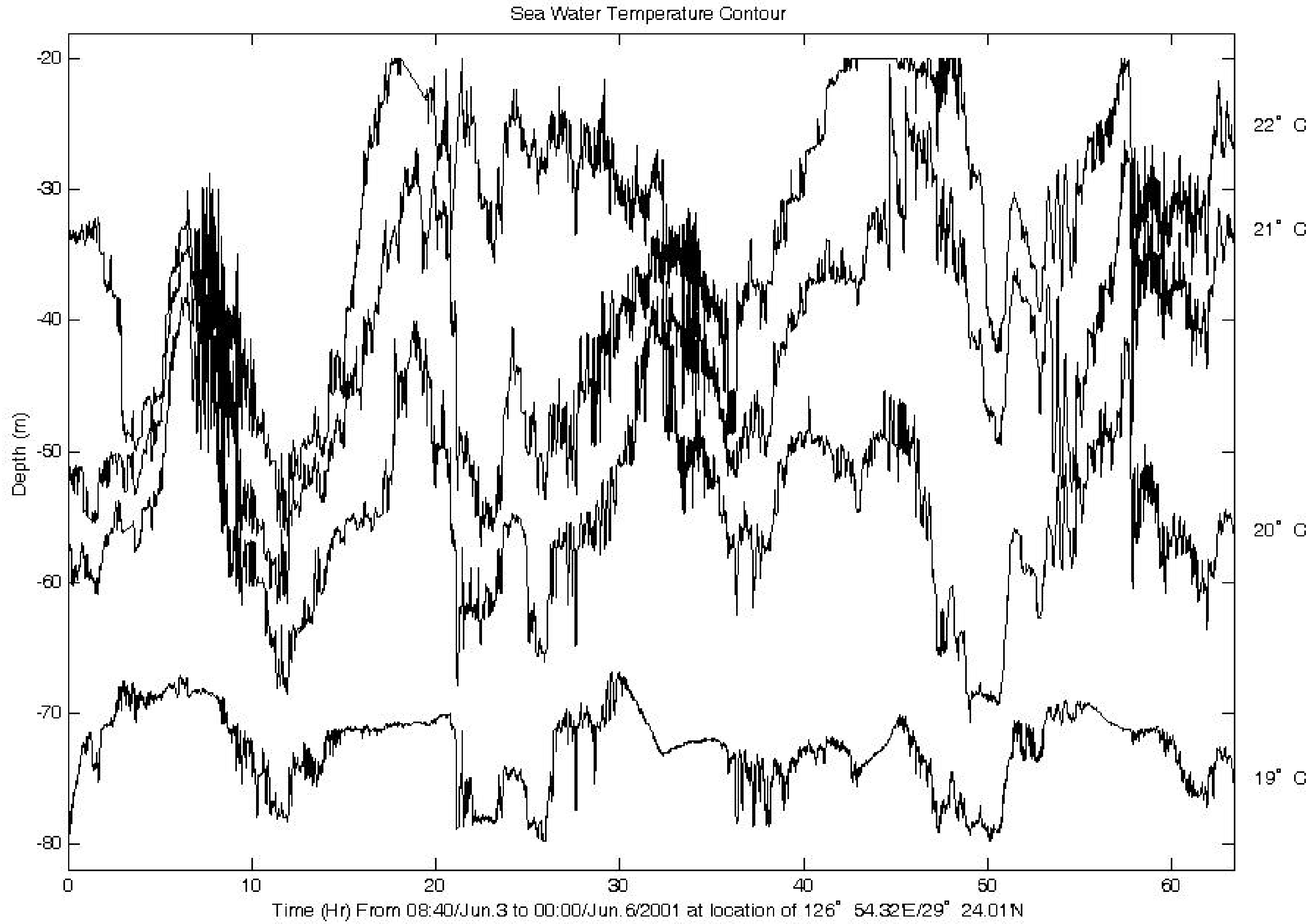
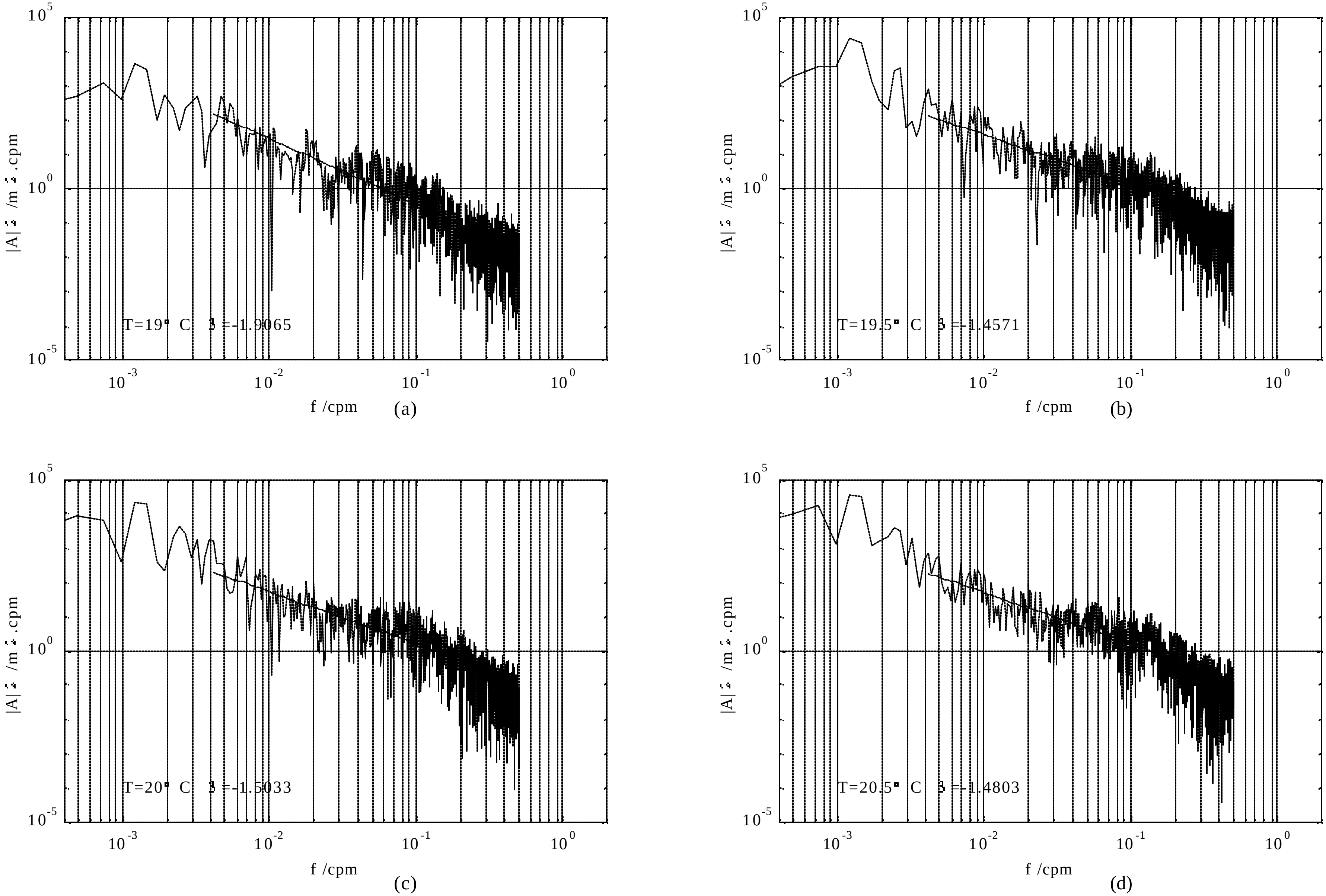


Figure 3 Vertical displacement curves at different temperature from 08:40/Jun.3 to 00:00/Jun.6/2001


T=19° C β=-1.9065
T=19.5° C β=-1.4571
T=20° C β=-1.5033
T=20.5° C β=-1.4803
f /cpm
(a)
(b)
(c)
(d)

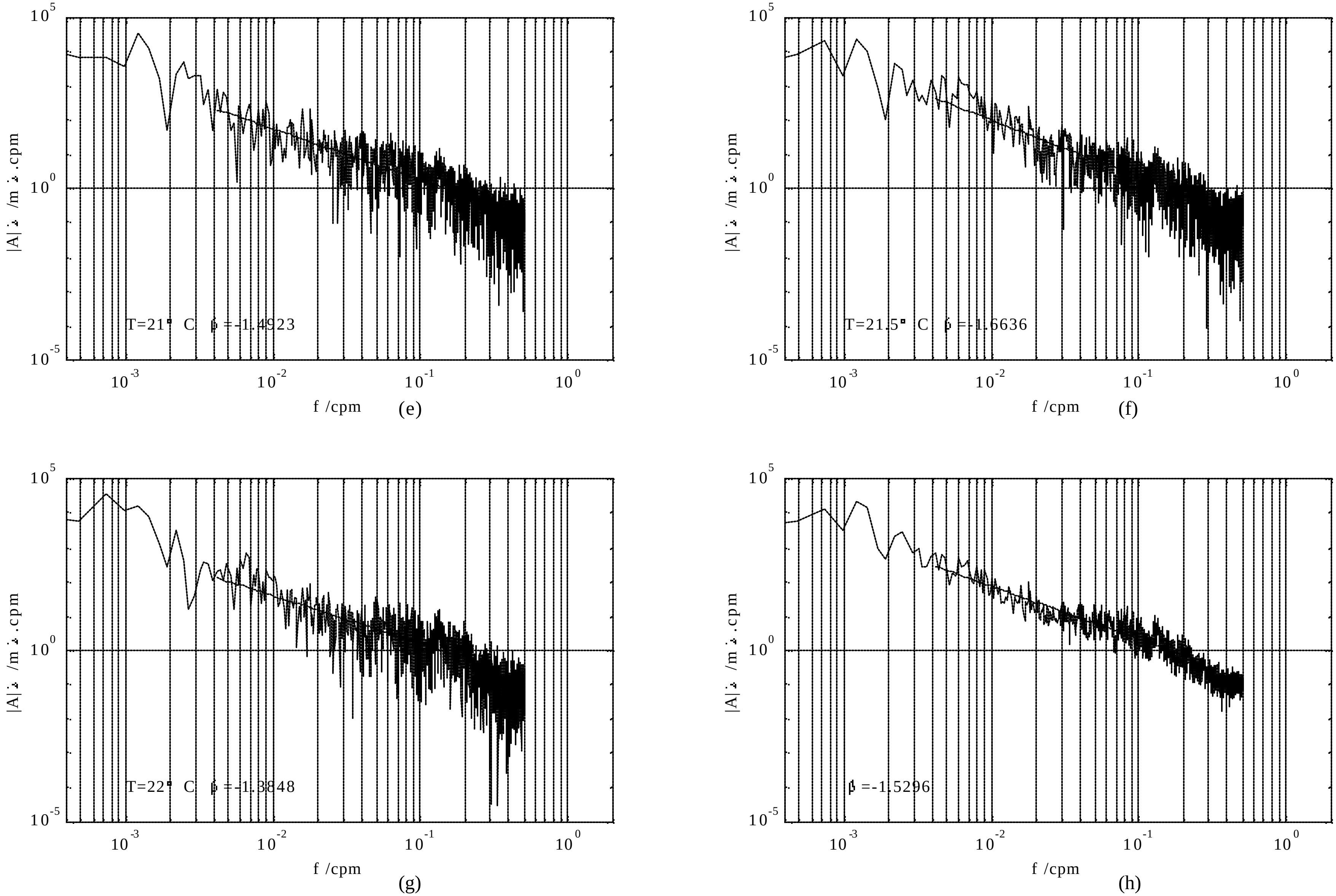


Figure 4 Power spectrum of vertical particle displacement at different temperature

Table 1 The attenuation coefficients of vertical displacement power spectrum at different temperature

T(^{o}C)	19	19.5	20	20.5	21	21.5	22
b	1.9065	1.4571	1.503	1.4803	1.4923	1.6636	1.3848

During the frequency range of $w_i < w < N(z)$, the spectrum attenuation coefficients of the vertical displacement power spectrum are about -1.5

- **Inertial frequency:** $w_i = 2\Omega \sin j$ **=0.0043cpm**
- **Brunt-Vaisala's frequency:** $N(z)$

4. Normal mode of internal wave and its dispersion

Wave Equation of internal wave:

$$\frac{\partial^2 y_j(\boldsymbol{z})}{\partial \boldsymbol{z}^2} + \left[\frac{N^2(\boldsymbol{z}) - w^2}{w^2 - w_i^2} \right] \boldsymbol{k}_{hj}^2 y_j(\boldsymbol{z}) = 0$$

$\boldsymbol{k}_{hj}$: horizontal wave-number of j^{th} normal mode of internal wave

Brunt-Vaisala's frequency:

$$N^2(z) = -\frac{g}{r(z)} \frac{\partial r(z)}{\partial z} = ag \frac{\partial T(z)}{\partial z} - bg \frac{\partial S(z)}{\partial z}$$

Eigenfunction Approximation by Talor's Series Expansion:

$$y_j^{n+1} = y_j^n + y_j^{n}{}' h + y_j^{n}{}'' \frac{h^2}{2!} + y_j^{n}{}''' \frac{h^3}{3!} + \cdots$$

$$y_j^{n-1} \approx y_j^n - y_j^{n}{}' h + y_j^{n}{}'' \frac{h^2}{2!} - y_j^{n}{}''' \frac{h^3}{3!} + \cdots$$

$$y_j^{n}{}' \approx \frac{y_j^{n+1} - y_j^n}{h} + \left[\frac{N^2(z_n) - w^2}{w^2 - w_i^2}\right] k_{hj}^2 y_j^n \frac{h}{2}$$

$$y_j^{n}{}' \approx \frac{y_j^{n} - y_j^{n-1}}{h} - \left[\frac{N^2(z_n) - w^2}{w^2 - w_i^2}\right] k_{hj}^2 y_j^n \frac{h}{2}$$

$$y_j^{n-1} + \left\{-2 + h^2 \left[\frac{N^2(z_n) - w^2}{w^2 - w_i^2}\right] k_{hj}^2\right\} y_j^n + y_j^{n+1} = 0, \qquad n = 1,2,\cdots,N-1$$

Boundary Condition:

$$y_j^0 = 0 \qquad \text{and} \qquad y_j^N = 0$$

Wave Equation:

$$\boxed{\mathbf{A}(k_{hj}^2)\mathbf{?}_j = 0}$$

Eigenfunctions

Eigenvalue Equation:

$$\boxed{\det\left\lfloor \mathbf{A}(k_{hj}^2) \right\rfloor = 0}$$

Phase/Group Velocities
of Normal Modes

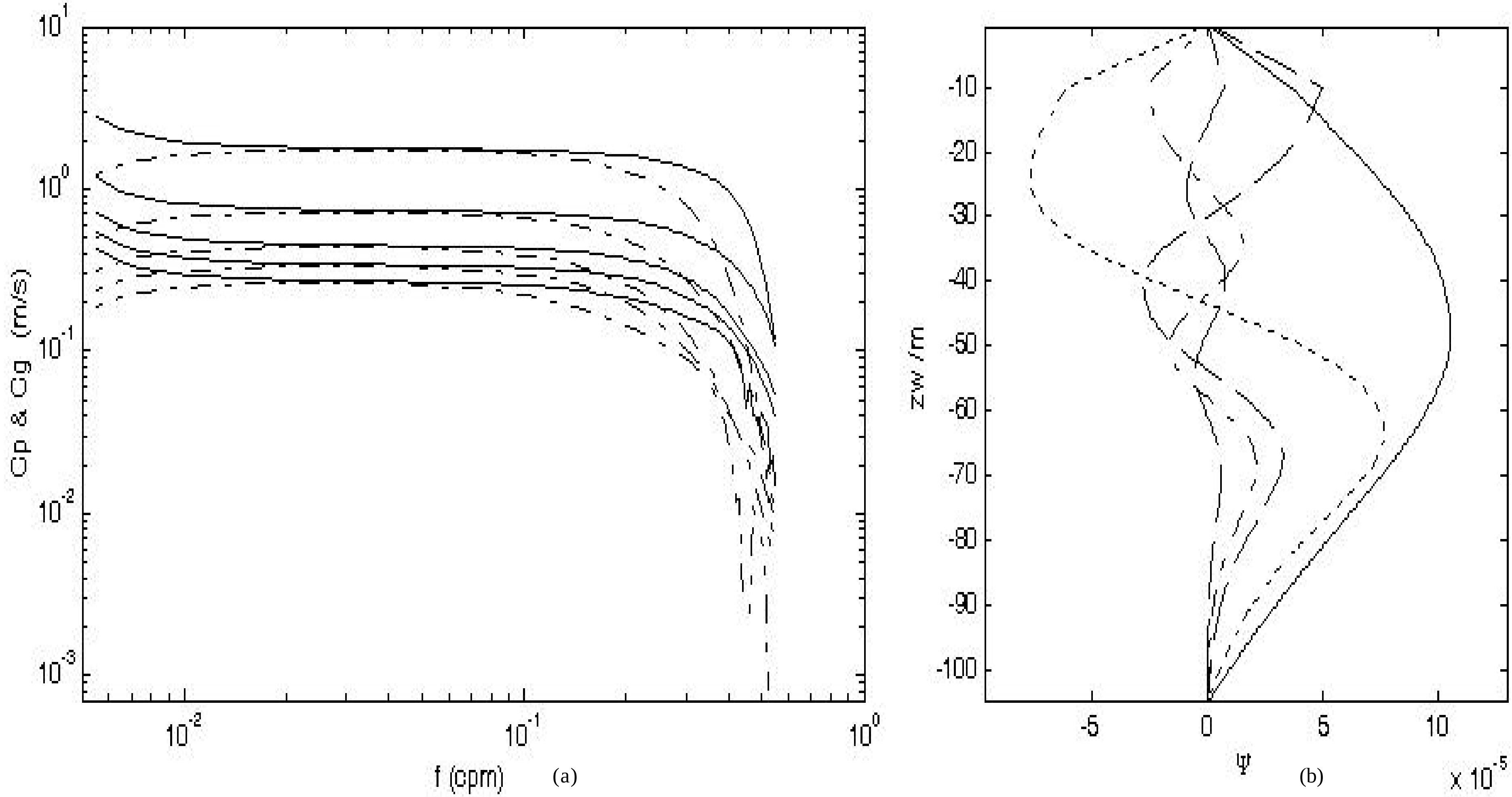


Figure 5 Phase velocities, group velocities and eigenfunctions of the first five normal modes of internal wave

At frequency of 0.05cpm, Phase/Group Velocities:

- 1th normal mode : 1.77m/s and 1.73m/s
- 2th normal mode : 0.73m/s and 0.71m/s
- 3th normal mode : 0.44m/s and 0.43m/s
- 4th normal mode : 0.34m/s and 0.33m/s
- 5th normal mode : 0.27m/s and 0.26m/s

$$\mathbf{?}_j = [y_j^0, y_j^1, y_j^2, \cdots, y_j^N]$$

$$\mathbf{A}£½\begin{bmatrix} 1 & 0 & & & & & \\ 1 & g_1 & 1 & & & & \\ & 1 & g_2 & 1 & & & \\ & & \ddots & \ddots & \ddots & & \\ & & & 1 & g_{N-2} & 1 & \\ & & & & 1 & g_{N-1} & 1 \\ & & & & & 0 & 1 \end{bmatrix}_{(N+1)\times(N+1)}$$

Here, $g_n = -2 + h^2\left[\frac{N^2(z_n) - w^2}{w^2 - w_i^2}\right]k_{hj}^2 \qquad n = 1, 2, \cdots, N-1$

5. Conclusion

(1)The internal wave owns the feature of internal semi-diurnal tides with strong fluctuations.

(2)There exist three elevation solitons which are separated from internal tides.

(3)The mean spectrum attenuation coefficient of the vertical displacement power spectrum is about -1.5.

(4)The estimated mean group velocities of five normal modes of internal wave at frequency of 0.05cpm are 1.73m/s, 0.71m/s, 0.43m/s, 0.33m/s and 0.26m/s, respectively.

THANKS